MISSOURI DEPARTMENT OF NATURAL RESOURCES
WATER PROTECTION PROGRAM, WATER POLLUTION CONTROL BRANCH

CONCENTRATED ANIMAL FEEDING OPERATION
PLANT AVAILABLE NITROGEN PROCEDURE

December 8, 2005

The Plant Available Nitrogen (PAN) method predicts the typical amount of nitrogen that is expected to be available to plants based on the median or average values from the reference publications listed herein. Actual nitrogen available to plants during a growing season may be more or less than the predicted values due to climatic variations.

A. PAN Equation

The purpose of the PAN Equation is to determine the appropriate process waste application rate. The PAN Equation can be written in the following form:

$$Application\ Rate = \frac{CNR - sRON - mRON}{PAN}$$

CNR: CNR is the Crop Nitrogen Requirement. This is the amount of nitrogen needed for the crop growth based on recent yield data for that site where available or a realistic yield goal when yield data is not available. Book values or nitrogen fertilizer recommendations from soil testing laboratories may be used to obtain this value.

sRON: sRON is the Soil Residual Organic Nitrogen. This is the nitrogen available to plants from the nitrogen released by mineralization of organic matter. This value is already accounted for in the listed book values for Crop Nitrogen Requirements of perennial crops. This is also already accounted for in most fertilizer recommendations. In these cases assume that sRON is zero. Otherwise calculate sRON by looking up the Soil Availability Factor in Table 3 and using the following equation:

$$sRON = [Percent\ Organic\ Matter]\ x\ [Soil\ Availability\ Factor]$$

mRon: mRon is the Manure Residual Organic Nitrogen. This is the nitrogen available to plants from the application of animal wastes in the past. Calculate mRON by looking up the Availability Factors in Table 2 and using the following equations:

$$Year\ 2\ mRON = [Year\ 2\ Organic\ Nitrogen]\ x\ [Year\ 2\ Availbility\ Factor]\ x\ [Year\ 2\ Application\ Rate]$$

$$Year\ 3\ mRON = [Year\ 3\ Organic\ Nitrogen]\ x\ [Year\ 3\ Availbility\ Factor]\ x\ [Year\ 3\ Application\ Rate]$$

$$mRON = [Year\ 2\ mRON] + [Year\ 3\ mRON]$$

PAN: PAN is the Plant Available Nitrogen. This is the nitrogen that is theoretically available to the plants from the current application of manure. Calculate PAN by looking up the Availability Factor in Table 2 and the Retention Factor in Table 1.

$$PAN = [Organic\ Nitrogen]\ x\ [Availability\ Factor] + [Ammonia\ Nitrogen]\ x\ [Retention\ Factor] + [Nitrate\ Nitrogen]\ x\ [Retention\ Factor]$$

For process wastes stored in an anaerobic state, the nitrate nitrogen concentration will usually be negligible. In this case the nitrate nitrogen can be assumed to be zero. If the laboratory does not provide the organic nitrogen content it can be found from the following calculation:

$$[Organic\ Nitrogen] = [TKN] - [Ammonia\ Nitrogen + Nitrate\ Nitrogen]$$

Special Case: In the case that an operation is using the PAN procedure for planning purposes to calculate land area or the case that the same application rate of manure is used on a field year after year, the PAN equation can be simplified. Calculate the CNR and sRON as described. The mRON is then set equal to zero. Then the cumulative Availability Factor is used for calculating PAN.

B. Additional Information and Requirements

1. Crop nitrogen requirements can be obtained from the University of Missouri Publication, EQ 202, Table 1, (Required for Growth) or Livestock Waste Facilities Handbook, MWPS, April 1993, Table 10-3 or from a nitrogen fertilizer recommendation from a soil testing laboratory. Alternate reference publications may be used upon prior approval by the department.
2. If a crop is not harvested or grazed, the Crop Nitrogen Requirement should not exceed 40 lbs/acre for the planning year and grass vegetation must be maintained on the application site.
3. The application rates for land used for grazing cattle shall include both manure additions by cattle and crop nitrogen consumed by the cattle based on actual cow days per acre per year. The permit does not authorize grazing of cattle where prohibited by state statute under Chapter 350 R.S.Mo.
4. Supplemental nitrogen may be added to crops when determined necessary for proper plant growth based on testing of plant vegetation or soil nitrate testing during the growing season. Supplemental commercial fertilizers planned or used must be subtracted from the Crop Nitrogen Requirement.
5. PAN Procedure calculations, application amounts, crop yields and crop removal rates shall be listed in the annual report.
6. Alternate nitrogen availability factors may be considered based upon site-specific conditions for each field and submittal of scientific justification.
7. Primary references used herein are:
   a. Livestock Waste Facilities Handbook, Midwest Plan Service, MWPS-18, April 1993.
   b. National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, USDA, NRCS, April 1992 and current supplements.
   c. Managing Nitrogen for Groundwater Quality and Farm Profitability, Soil Science Society of America, Inc., 1991.
   d. Soil Test Interpretations and Recommendations Handbook, University of Missouri, Department of Agronomy, December, 1992.

C. Tables

Table 1. Retention Factor

Type of Nitrogen	Surface Application	Immediate Incorporation or Subsurface Injection
Ammonia Nitrogen	0.6	0.9
Nitrate Nitrogen	0.9	0.9
Note: Alternately, Table 2 or 3 should be used where field drainage information is known.		

Table 2. Availability Factors

Source	Year 1	Year 2	Year 3	Cumulative
Anaerobic Lagoon	0.35	0.18	0.09	0.62
Liquid Storage Basin (except poultry)	0.35	0.18	0.09	0.62
Poultry (storage basins and dry litter)	0.60	0.10	0.05	0.75
Manure Solids (beef, dairy and swine)				
Without Bedding	0.35	0.18	0.09	0.62
With Bedding	0.25	0.13	0.07	0.45
Note: Year 1 is the current year of manure application; Year 2 is the previous year of manure application; and Year 3 is the manure application two years ago.				

Table 3. Soil Availability Factor

Growing Season	Cation Exchange Capacity (CEC) <10	10-18	>18
Summer	40*	20	10
Winter	20*	10	5
* Note: If CEC is less than 10 and the organic matter is 1.5% or greater, the total SRN is constant at 60 pounds nitrogen for summer and 30 pounds for winter			

Table 4. Conversion Factors

Desired Units	Conversion Factor
lbs/acre inch	0.226
lbs/1,000 gallons	0.0083
lbs/100 cubic feet	0.0062
lbs/ton (wet weight)	0.002
Note: Laboratory testing results are converted to more usable units as follows: [mg/: or mg/kg or ppm] x [Conversion Factor] = [lbs/unit volume]	

D. Worksheet

Operation Name: _____ Permit Number: _____

Field ID: _____ County: _____ Acres: _____

Land Owner: _____

1. Animal Waste Nutrients

Animal Type _____ Nutrient Source (i.e. lagoon, deep pit, etc.) _____

Testing Results units (check one)
_____% _____ppm _____mg/L or mg/kg ____lbs/ton _____ lbs/1000 gallons _____lbs/acre-inch

Test Results
Date of Sampling: _____
Laboratory: _____
Total Nitrogen/TKN: _____
Organic Nitrogen[1]: _____
Ammonia Nitrogen[1]: _____
Nitrate Nitrogen[2]: _____
Fertilizer Nitrogen Recommendation (optional): _____

[1]Organic Nitrogen or Ammonia Nitrogen can be calculate using the following equation:
Ammonia N = Total Nitrogen - Organic Nitrogen or Organic Nitrogen = Total Nitrogen – Ammonia N
[2]Assume zero (negligible) unless using a non-standard manure source, for example a mechanically aerated lagoon or compost

2. Soil Testing Results

Date of Sampling[1]: _____
Laboratory: _____
Cation Exchange Capacity (CEC) _____
Percent Organic Matter: _____

[1]Soil Testing should be done at least once every five years.

3. Unit Conversion

	Test Value from 1.		Conversion Factor from Table 6.		Desired value	Units	
Total Nitrogen	_____	x	_____	=	_____	_____	(a)
Organic Nitrogen	_____	x	_____	=	_____	_____	(b)
Ammonia nitrogen	_____	x	_____	=	_____	_____	(c)
Nitrate Nitrogen	_____	x	_____	=	_____	_____	(d)

4. Crop Nitrogen Requirement

Crop(s) to be grown: _____
Recent Average Yield or Realistic Yield Goal: _____
Calculation of Nitrogen for yield goal (if applicable)_____
CNR = _____ (e) (See Section B.1 for allowable sources of this value.)
Source of CNR: _____

5. Soil Residual Organic Nitrogen, sRON

i. sRON = 0 (f) (lbsN/ac) for perennial crops,
ii. sRON = 0 (f) (lbsN/ac) when already factored into nitrogen recommendations, or
iii. sRON = _____(f) (lbsN/ac) = ____ % organic matter x _____ Soil availability factor (Table 5)

6. Manure Residual Organic Nitrogen, mRON

i. mRON = 0 (g) (lbsN/ac) for several years of applying animal wastes at approximately the same rate. *(Use cumulative factor from Table 4 when calculating PAN in Section 7.)*
ii. mRON = 0 (g) (lbsN/ac) for planning purposes. *(Use cumulative factor from Table 4 when calculating PAN.)*
iii. mRON = 0 (g) (lbsN/ac) for no land application of animal waste in the past two years, or
iv. mRON =_____ (g) = _____(b) from Year 2 x _____Availability Factor, Table 4 for Year 2 x _____Application Rate 2 used in Year 2 + _____(b) from Year 3 x _____Availability Factor, Table 4 for Year 3 x _____Application Rate used in Year 3

7. PAN = Plant Available Nitrogen

PAN =_____ (h) (units as chosen from Table 6 in step 3) = _____(b) x _____ Availability Factor, Table 4[1] + ____ (c) x _____ Retention Factor, Table 1 + ____ (d) x _____ Retention Factor, Table 1

[1]When using mRON = zero, due to several years of applying at approximately the same rate or for planning purposes, the retention factor will be the cumulative factor from Table 4. Otherwise it is the current year, year 1, factor from the same table.

8. Calculating the Application Rate

Application Rate = $\frac{CNR - sRON - mRON}{PAN} = \frac{(e) - (f) - (g)}{(h)} =$

$\frac{(\_\_\_\_\_) - (\_\_\_\_\_) - (\_\_\_\_\_)}{(\_\_\_\_\_)} =$ _____ _____ (volume units as chosen from Table 6 in step 3)

For Questions Contact: Missouri Department of Natural Resources, Water Protection Program, Agricultural Unit, P.O. Box 176, Jefferson City, Missouri 65102-0176 or by phone at (573) 751-1300.
Or contact your local University Extension or Natural Resources Conservation Service.